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ABSTRACT

To enhance both teaching and learning in an advanced undergraduate elective course on the interrelationships of plants and human affairs, the computer was used for information retrieval, multiple choice course review, and the running of three simulation models--plant related systems (e.g., the rise in world coffee prices after the 1975 freeze in Brazil), endangered species, and plants and human affairs. Reaction to all aspects of computer use were generally favorable, although students felt that they needed to spend more time in class discussing simulation results. (CHV)

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PLANTS AND HUMAN AFFAIRS:
EDUCATIONAL ENHANCEMENT VIA A COMPUTER

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Plants and Human Affairs: Educational Enhancement Via a Computer

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Introduction

Use of computers in undergraduate biological teaching is in its log phase of growth. Indications of this include increased participation of computers in biological teaching symposia held at the annual meetings of the American Institute of Biological Sciences, as well as growing numbers of articles on computers in biological teaching appearing in such publications as *Bioscience* and the *AIBS Education Review*. Another sign of increasing activity is the growing number of programs that deal with specific biological phenomena. Biological programs are available in large computing networks such as PLATO, from organizations such as CONDUIT, or from individual professors. This current increase in use of computers in undergraduate teaching also is evident from the results of a recent CONDUIT survey of 3,500 life sciences departments. This survey, overseen by Crovello, indicated a diverse level and type of instructional computing guidelines for their integrated use in biological teaching throughout an entire life sciences department. At Notre Dame, computers have been used in biological teaching at the undergraduate level in courses in general biology, ecology, genetics, physiology, plant taxonomy, ecology, and in plants and human affairs. The purpose of this paper is to describe our actual experience with the use of computers in one of these courses, "Plants and Human Affairs." We believe that its use has enhanced both teaching and learning, and that our innovative uses might be of value elsewhere.

Plants and Human Affairs and the Computer Facilities It Uses

Plants and Human Affairs is a university-wide elective course (one open to students in every major). The kind of credit a student receives depends on the department from which he/she comes. With the exception that students must be juniors or seniors, there are no prerequisite courses or experience, either in biology or in computing. Enrollment in Plants and Human Affairs varies between 65 and 100 students each spring semester. It is not a required course for anyone, although it is a suggested elective for the Education for World Justice option at Notre Dame. The purpose of this lecture-only course may be summarized (perhaps too tersely) as follows: without plants we wouldn't be, and without plants we wouldn't be as happy.

Notre Dame's 9,000 students are served by the University's IBM 370/158 computing facility. It permits simultaneous use of forty-five remote terminals in addition to a batch processing background. The biology department has six terminals located in its new Life Sciences Building, but these are not used for Plants and Human Affairs for several reasons, including: insufficient availability of an adequate number of terminals; unavailability of the terminals in the biology department for extended hours throughout the day and night; and lack of funds to retain adequate supervisory personnel.

Plants and Human Affairs uses the IBM 370 exclusively. The department's own Tektronics 4051 and its Nova 1200, even though the latter has a time-sharing option

available, are not used in Plants and Human Affairs, primarily because the department cannot supply a sufficient number of dedicated terminals required for such a large class enrollment.

Types of Computer Use in Plants and Human Affairs

The authors' educational philosophy centers on the concept that the wise use of computers can enhance undergraduate teaching and learning. It has been our policy that when some use does not accomplish this, it is discontinued. In addition, we believe that almost every undergraduate course can benefit from some amount of computer usage, even if it is only to permit more efficient information retrieval from the literature. Arising almost as a corollary of this philosophy is our commitment to reduce the feeling among undergraduate students that they are simply passive parasites on the educational system. Our major approach to alleviate this feeling has been to encourage students to create computer programs which would be useful in subsequent offerings of undergraduate courses, and also to create the actual biological questions, answers, and replies to answers which are used in on-line multiple choice course reviews. This will be described in more detail later.

Computers can be used in undergraduate teaching in seven ways: information retrieval, automated data accumulation, data analysis, simulation of biological phenomena, decision-making, online control of experiments, and multiple choice course review. Plants and Human Affairs uses computers in three of these ways: information retrieval, multiple choice course review, and simulation. We now shall discuss each of these three uses in greater detail.

Information Retrieval

As its title implies, Plants and Human Affairs covers a huge spectrum of knowledge, from cellular biology and plant anatomy up through world economics and environmental quality as they are affected by plants. One of a professor's biggest problems in such a course is to remain up-to-date with the literature. This is not just the problem of keeping informed as to what has been published, but also of keeping informed as to what references and information he has already added to his files. Consequently, several years ago Crovello created a personal computerized data bank of literature references of interest to him in either teaching or research. Each reference is deep-indexed, and the names of the authors, date, title, citation, and deep-indexed subject numbers are entered into the computer data bank. Any combination of key words and subject numbers can be searched for with a simple descriptive command. For example, to provide the lecturer with all references on plants and poisons, the subject number for plant, for poisons, and the Boolean logic connector are all that must be entered onto a punched card for computer searching. To be extra certain of not missing any relevant references in the data bank, the subject words "poisoned," etc., which might appear in certain titles, also could be looked for. Currently, Crovello's personal literature bank contains about 7,500 references.

Because Plants and Human Affairs covers so much material, and many students are seeing such material for the first time, heavy reliance is made on visual aides, particularly two by two projector slides. In a manner similar to literature references, Crovello's personal slide collection includes over 6,000 slides. For each slide, a reference number to it, a description of its botanical contents, and its relation to different parts of the course have been entered into a separate computerized data bank. Thus, when preparing a lecture on a given topic throughout the semester, Crovello merely has to request all slides with that particular subject number. Plant names are available in the description of each slide so that if Crovello wanted all slides of a given genus or of a given family he again merely has to input the particular

names of interest. All such searches are relatively inexpensive, remaining below five dollars.

Multiple Choice Course Review

Making multiple choice question sets available at remote computer terminals for use at the student's convenience is not new. In Plants and Human Affairs we use a rather simple driver program written in PL1 to present a question to the student, who then chooses an answer. After each choice the computer indicates whether his/her choice is correct or incorrect. But in addition, if the choice is incorrect, an explanation is given as to why it is incorrect. If the choice is correct, then additional subject information is provided. As teachers throughout the country have discovered, this extra information is a great incentive to students, even to the point of their deliberately choosing incorrect answers after they have chosen the correct one to obtain the explanation for the incorrect choices. The innovative feature of the multiple choice course reviews in Plants and Human Affairs is that the students themselves create the questions. Throughout the semester, as a certain section of the course is completed, students are required to submit a multiple choice question, five answers, and an explanatory reply for each of the answers. After being checked and accepted for correctness and suitability by a teaching assistant, the information is entered into the Plants and Human Affairs computerized data bank, and is accessible to all students. If certain questions, answers, or replies are incorrect or are not suitable, they are returned to the student who then can choose to correct and resubmit them. If the student brings the questions up to standards, he/she can receive almost full credit. Or the student can choose not to correct them and thus be satisfied with a lower grade than is possible. This option to enhance one's grade is a strong stimulus to most students.

Advantages of requiring students to create their own questions are several, including creating of the need for them to search their notes thoroughly and to go into the relevant literature to create a question, five answers, and five replies. Creation of the question is usually not difficult, but obtaining five answers and meaningful replies to these answers is. A second advantage is that this assignment has removed the need for short lecture quizzes, which though short, still take up valuable class time. In addition, students also learn that creation of meaningful multiple choice questions and answers is a difficult process. This realization regularly evokes a voiced, sympathetic feeling toward their teachers. Creating questions, answers, and replies also decreases students' feelings of being passive participants in the educational process, a continuous problem in large lecture courses. Finally, because they see their contributions integrated into a large multiple choice course review data bank from which they and their fellow students benefit, camaraderie among students increases.

Actual review of these large sets of questions in the computer data bank is *not* required. However, an incentive for students to do so is the inclusion of a certain number of actual questions from the data bank on examinations throughout the semester. This is motivation enough for the students to review the questions and to understand what they mean. Also important is that students' attitudes toward reviewing the questions change from the negative one of having to do another assignment to the positive one of taking advantage of useful study aid. A further advantage of *not requiring* students to review the multiple choice questions is the complete elimination for the teaching staff to check that each student has reviewed some required number of questions and answers.

Because many students do not have a background in computers and are unfamiliar with some aspects of activating data sets and programs from remote terminals, we have made access to the review of multiple choice questions as simple as possible. Students merely have to learn to log on to the system. Once in TSO's READY mode, a stu-

dent simply types the code of the particular segment of the course for which questions are desired (for example, PAHA 1, PAHA 2). These data sets are available throughout the semester for review by the student at his or her leisure

Simulation of Plant Related Systems

Given the goal of the course, and of students' interests, emphasis on indepth studies of plant systems involves applied botany more than basic botanical areas. The two simulation models used in Plants and Human Affairs have three purposes: (1) to provide deeper insights and knowledge of the system, (2) to permit students to gain a stronger understanding of the complex interrelationships among parts of a system, and (3) to show that these relationships affect the ultimate behavior of the system. For example, what are the causes of the large rise in 1977 coffee prices around the world? Is it just due to the weather freeze in Brazil which killed 75 percent of coffee plants?

A further purpose of the simulation models is to bring about changes in behavior of the students that is based on more fact and understanding (for example, to be more of a vegetarian or not, or to change voting decisions). The first simulation model to be described is the endangered species model, and the second is a model of world agricultural production and consumption called the PAHA World Model.

The Endangered Species Model

Written in the BASIC programming language for wider transportability, the endangered species model permits students to gain insights into what components of society and of the natural world affect the endangered status (actual or legal) of species. Simultaneously, students gain insights into how various other components of society interact and affect each other. Among the major components considered are the current endangered status of species, current status of endangered species legislation, the public's attitudes towards endangered species, economic status of the country, and environmental index. There are several ways in which the simulation can be played. Long before sitting down at a terminal, students are provided with detailed mimeographed information on the endangered species model, as well as the current status of endangered species, and of the other components which are available in the system (for example economic index, sociological index, etc.). Students are asked to do two things to help them to understand how the current status of endangered species came about: to determine what components interact directly with other components, and to determine what the values of different components have been on a relative scale over the last decade. For example, has endangered status increased, decreased, or fluctuated over the last ten years? Have the attitudes of politicians and of the public toward environmental protection and endangered species changed? Once students have made certain decisions about these two areas, then they input their information on relationships and relative values of the components over the last ten years into the computer model. Their printout gives them what the present status should be, based on the result of their assumptions and data. Then they know how close their ideas of cause and magnitude are from the truth. Of course there is more than one solution to this system and this in itself is a remarkable discovery for many students.

Another way to exercise the model is to ask students to depict relationships among the components and to provide what they feel have been the relative values of each component over each of the last ten years. The computer then will take these data and plot a forecast for the next ten years. Thus, students quickly can see how incorrect they were, and learn the consequences of our society remaining on the course on which it appears to be.

The endangered species model is a simulation, but we prefer to refer to it as qualitative simulation rather than a regular, more quantitative systems analysis. Given the problem

of avoiding extreme complexity for students in a nonquantitative course, the problem of component definition, and the problem of obtaining reliable values of characteristics of each component (for example, the public's attitudes), it seemed best to keep the model in a more qualitative mode.

The Plants and Human Affairs World Model

This is a relatively simple but realistic model of world agricultural production and consumption. Its source is the World III Model of the Club of Rome written in the Dynamo II computer language. Under the direction of Professors J. Forrester and Dennis Meadows at Massachusetts Institute of Technology, the World III Model has a subroutine called, Agricultural Sector With Exogenous Inputs. The Plants and Human Affairs World Model has been adapted from this. Our model simulates the interaction of such factors as land fertility, population, and total agricultural investment to produce values over time for food produced, land yield, and amount of arable land.

Students are given detailed mimeographed information on the Plants and Human Affairs World Model. Discussions on the model are held in class before the students sit down at a computer terminal. The students' goal is to study the behavior of the agricultural model given certain changes that they choose. Conversely, their assignment can be to determine what components of the model must be manipulated and what values these components must have to achieve a certain condition after some specific number of years. This is a rather more complex model than the endangered species model and it is presented after the endangered species model has been analyzed. After students have made their runs with results of various perturbations, the data are then integrated and analyzed to discover any particular patterns. A critique of the relationships among the components as well as of the particular form of equation relating them is also made. Again, the purpose of the simulations in the course is not to have students develop a more reliable or specific world model, but to gain insights into the complex interrelationships involved in an aspect of Plants and Human Affairs.

Advantages and Disadvantages of Computers In Plants and Human Affairs

Much of the information reported in this section was obtained from an anonymous questionnaire which was distributed to all students at the end of the semester. In addition, constant reactions were received from students throughout the semester. We first make some general comments.

For many students, particularly nonscientists, this is the first experience with computers. All survive, and many find it to be less painful and more profitable than expected. We have sensed an increase in understanding of the course material, credit for which (although not rigorously tested) appears partly due to the use of computers. We found computers to be useful both to the professor in enhancing his teaching effectiveness, and to students in increasing their learning effectiveness. We have been able to teach better what we have long taught, and to teach easily what was previously difficult. We have seen increased interest by students in the subject matter, and have been able to permit students, at least in part, to learn at their own pace. By using the University-wide computer facilities, including computer terminals, we have been able to do this at little cost to the department. This is important, particularly in justifying computer use to colleagues in biology who feel that there are more important uses for limited departmental funds.

More specifically, the use of computerized information retrieval has saved large amounts of time in the location of slides for particular lectures and of literature references for specific segments of the course. This is especially true in Plants and Human Affairs because one reference or one slide often is relevant to several parts in the course.

In the future, we hope to permit students to use the literature data bank to help them in preparing term papers which must analyze in detail some aspect of Plants and Human Affairs.

Use of the computer for multiple choice course review has met with good success, particularly because there is no requirement for students to review any set number of questions on the computer. Many indicate that they have a much better grasp of the subject matter after reviewing the questions, answers, and replies. While at first some complain about having to create questions, answers, and replies, ultimately they feel that the forced experience of getting into the primary literature and of reviewing their notes is worthwhile. A current problem which we are seeking to rectify is the redundancy of several questions in the data bank. This requires monitoring by teaching assistants who in addition to being biologists also must be familiar with computerized file manipulation.

Our simulations of plant-related systems do not yet appear to have the best combination of printed matter, actual simulation, and class discussion. The biggest problem appears to be that the professor over-estimates the students' ability to grasp any kind of quantitative presentation (even in the form of a systems diagram) in the limited time available. Much more time appears to be required before students run actual simulations to permit them to understand more clearly what the purpose of each simulation is, and the mechanics of running and modifying these simulations. In addition, many students suggested on their questionnaires that more time be spent in class discussing the results and meaning of the simulations after they are run.

Conclusions

Computers are used in an advanced undergraduate Plants and Human Affairs course which is open to all juniors and seniors at the University. Computers were introduced to enhance both teaching and learning in the course. Major uses involved information retrieval, multiple choice course review, and simulation of plant-related systems of relevance to society. Reaction to all aspects of computer use in general has been good, but efforts must still be made to enhance understanding and clarity of the more difficult assignments, particularly those involving simulation. We believe that students benefit from the use of computers in Plants and Human Affairs, and while computers will not replace good teachers, they can enhance their effectiveness.

Note

Correspondence with regard to the contents of this paper should be directed to Professor Crovello.

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